LOCKHEED MISSILES & SPACE COMPANY

HUNTSVILLE RESEARCH & ENGINEERING CENTER

HUNTSVILLE RESEARCH PARK

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EXPERIMENTAL DAMPING STUDIES

MONTHLY PROGRESS REPORT

20 August 1965

Contract NAS8-20088

Prepared for the George C. Marshall Space Flight Center
Huntsville, Alabama

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FOREWORD

This document contains a report of progress on Experimental Damping Studies, Contract NAS8-20088, covering the period 6 July to 5 August 1965. The purpose of this study is to:

- investigate analytical procedures for determining damping properties of complex structures
- develop improved experimental techniques for measuring damping
- prepare and conduct an experimental study of the above techniques using the Langley 1/5-scale model of the Saturn I vehicle
- compare results with those obtained from full-scale Saturn I tests, and
- compose a detailed technical report describing the results of the developmental program.

SUMMARY

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Testing of the "booster empty" model configuration was completed during the performance period by obtaining decay records and force-frequency relationships for five vibratory modes.

The model booster was then ballasted to simulate the weight at maximum dynamic pressure (booster 48% full). Frequency response curves were obtained at six accelerometer locations with the shaker mounted at Model Stations 24 and 345. Three primary bending modes were identified, their deflection shapes were measured, and decay records were obtained at 1, 1.4, 2, 5, 10, 15, and 20 lb force levels.

A cursory investigation of the booster tank cluster modes, which are prevalent with ballasted tanks, will be performed to complete the testing of the "48% full" configuration. Testing will be initiated on the "100% full" booster on 23 August and tentative test completion date is 10 September 1965.

Some difficulties were encountered in the theoretical analyses of the model vibrations. The basic problem seemed to be the mathematical representation of the upper and lower connections of the center LOX tank and the rest of the structure. Corrective procedures for this problem are being initiated.

1.0 WORK ACCOMPLISHED

1.1 Booster Empty

Damping Investigation: The decay time histories for five model vibratory modes were obtained at force levels of 1, 1.4, 2, 5, 10, 15, and 20 lb The MB-S 31 shaker, installed at Model Station 345, was used to excite the model. Because of the inherent noise and distortion in the unfiltered accelerometer signals, velocity pickups, integrated to displacement, were used as decay signals. A further improvement in accuracy was obtained by increasing the initial pickup signal trace deflection to approximately 5" D.A.

The MB-S6 shaker was installed at Model Station 345 and decay records were obtained at force levels as high as 60 lb, for all but the first bending mode. Considerable tower motion occurred in the 10-20 cps range, which affected the force-model response relationship in this range. In addition, this shaker appeared to introduce additional damping in the system at the higher modes.

The force-frequency and force-tip amplitude relationships are tabulated on Figure 1 and illustrated on Figures 2 through 6 for the basic five vibratory modes.

Booster Tank Pressure: The outer and inner booster tanks have been pressurized during the test program to 5 psi and 10 psi, respectively. An evaluation of the possible error induced by small fluctuations in applied pressure was performed by determining the mode frequencies while varying the cluster tank pressure from 0 to 6 psi. The results are shown on Figures 7 and 8. A linear frequency change is indicated for the first bending mode. As the variation in pressure during the program has been less than $\pm$ .25 psi, it is concluded that the induced frequency error for this mode is less than .03 cps.

Additional Mass: An alternate approach to the generalized mass calculation was attempted by clamping lead pigs to the spider beam cross members. The change in frequencies of the five basic modes were noted and the results are tabulated in Table I.

Booster 48% Full

Frequency Sweeps & Mode Shapes: Frequency sweeps at 5, 10, and 20 lb force were performed with the MB-S 31 shaker mounted independently at Model Stations 24 and 345. Accelerometer response was recorded at the following locations:

(a) Probe Location No. 2 (Station 388)

(b) Shaker (Station 24 or 345)

(c) Probe Location No. 42 (top of center booster tank)

(d) Probe Location No. 103 (center of No. 1 fuel tank)

TABLE I

FREQUENCY CHANGE WITH ADDED MASS AT MISSILE STATION 178
(SHAKER AT M.S. 345)

Weight Added lb	Frequency 10 lb Force	Frequency 15 lb Force	Frequency 20 lb Force
0	12.61	12.47	12.40
136.5	11.61	11.55	11.50
259.5	10.91	10.84	10.78
0	41.46	41.22	41.02
136.5	37.94	37.61	37.47
259.5	34.07	33.81	33.62
0	48.78	48.69	48.64
136.5	48.19	48.12	47.87
259.5	47.68	47.57	47.42
0	54.76	54.64	54.56
136.5	54.41	54.23	54.05
259.5	53.65	53.62	53.56
0	59.42	59.28	59.24
136.5	59.38	59.28	59.24
259.5	59.45	59.35	59.28

(e) Probe Location No. 803 (center of No. 8 LOX tank)

Figure 9 is a typical result of the sweeps.

Three bending modes were identified and their deflection shapes are shown on Figures 10, 11 and 12.

Damping Investigation: Decay time histories were recorded for the three bending modes of Figures 10, 11 and 12 at force levels of 1, 1.4, 2, 5, 10, and 20 lb. The results are shown in Figures 13, 14 and 15.

1.2 Theoretical Free-Vibration Analyses

Theoretical free-vibration mode shapes, natural frequencies, and generalized mass are needed for the 1/5-scale model of the SA-1 vehicle for a booster empty condition, booster 48% fueled condition, and booster 100% fueled condition. Preparation of external input data for use with Lockheed's multi-beam program for these three conditions is complete.

Successive runs of the multi-beam program have failed to produce what could be considered reasonable results for the three configurations mentioned above. Plotted mode shape output of the multi-beam program does not contain a shape that could correspond to a first overall bending mode for the model. Selection of constants internally input to the program that realistically "model" the constraints of the system (the program was originally developed for a different structure) is a critical problem area that has not been completely resolved. Several alterations are being considered and will be experimented.

1.3 Schedule

Booster 48% Full: The frequency response sweeps obtained from this configuration show several additional modes, some of which are cluster tank response.

These modes will be investiaged; however, the number of probe locations will be considerably reduced and damping-frequency records will be restricted to a few force levels. Testing of this configuration will be completed on 20 August 1965.

Booster 100% Full: Testing will be initiated with the "booster 100% full" on 23 August and the procedures used in defining the "booster 48% full" case will be repeated. Predicted completion date for all testing is 10 September 1965.

1.4 Milestones

1. Testing. . . . . 80% complete

2. Data Reduction. . . . . 50% complete

3. Data Analysis. . . . . 45% complete
4. Theoretical Analyses. . . . . 50% complete
5. Final Report. . . . . 25% complete

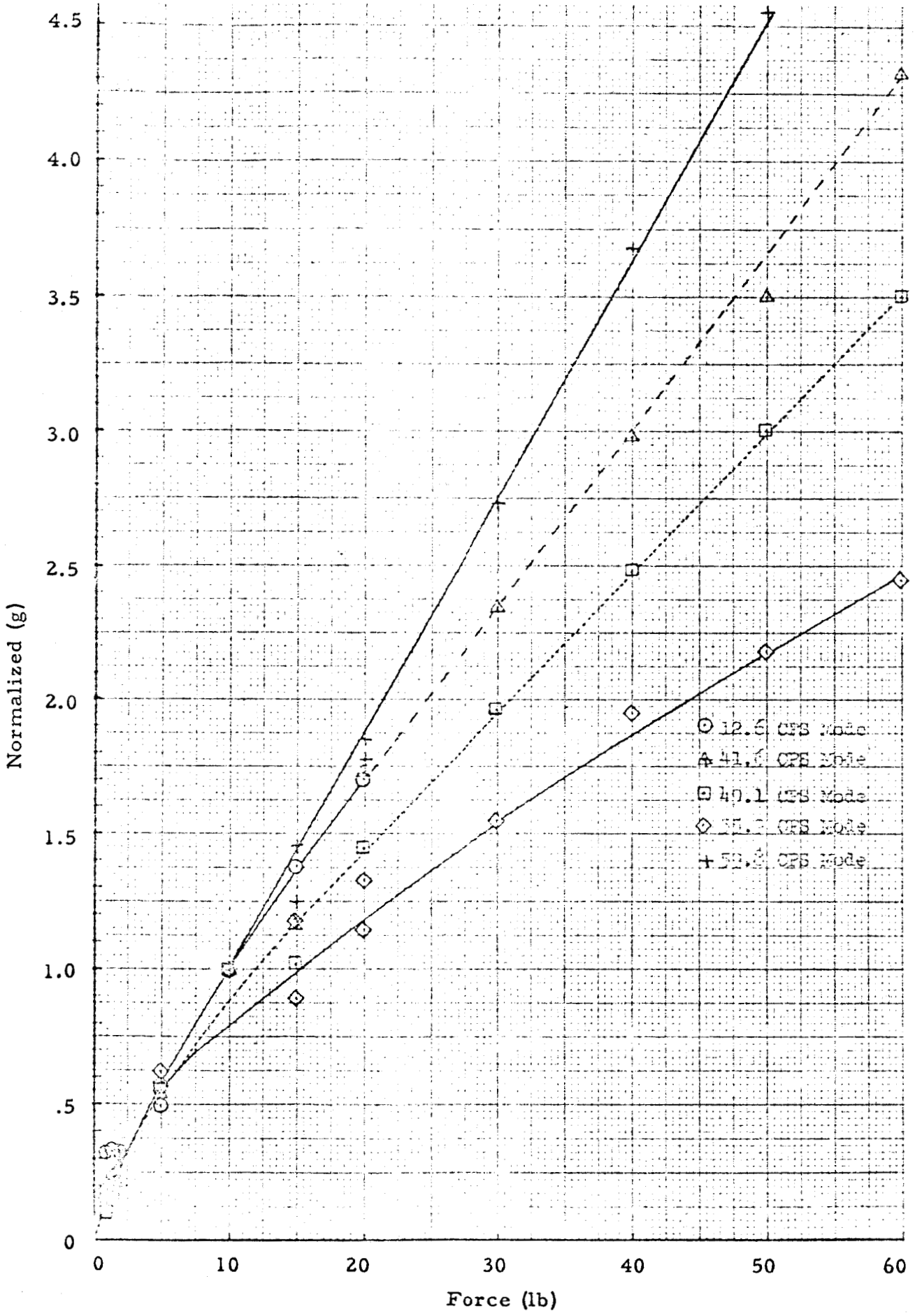
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
.5
0
Normalized (g)
0
10
20
30
40
50
60
Force (lb)
12.5 CPS Mode
41.6 CPS Mode
40.1 CPS Mode
55.5 CPS Mode
50.2 CPS Mode

Figure 1

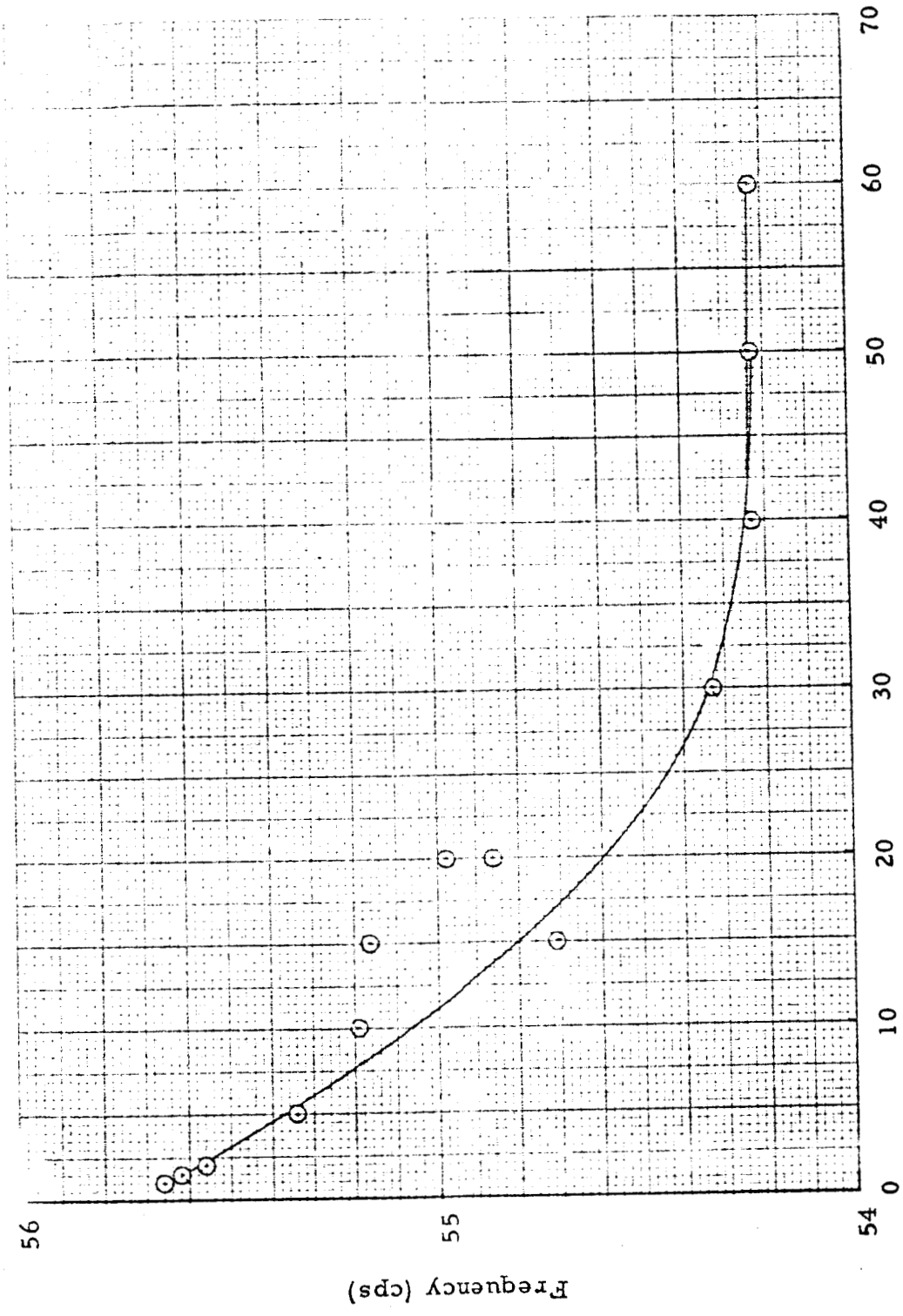

Figure 2 - Saturn SA-1 1/5 Scale Model Vibration Test Force vs Frequency (Empty Booster Fuel Shaker at Missile Station 345)

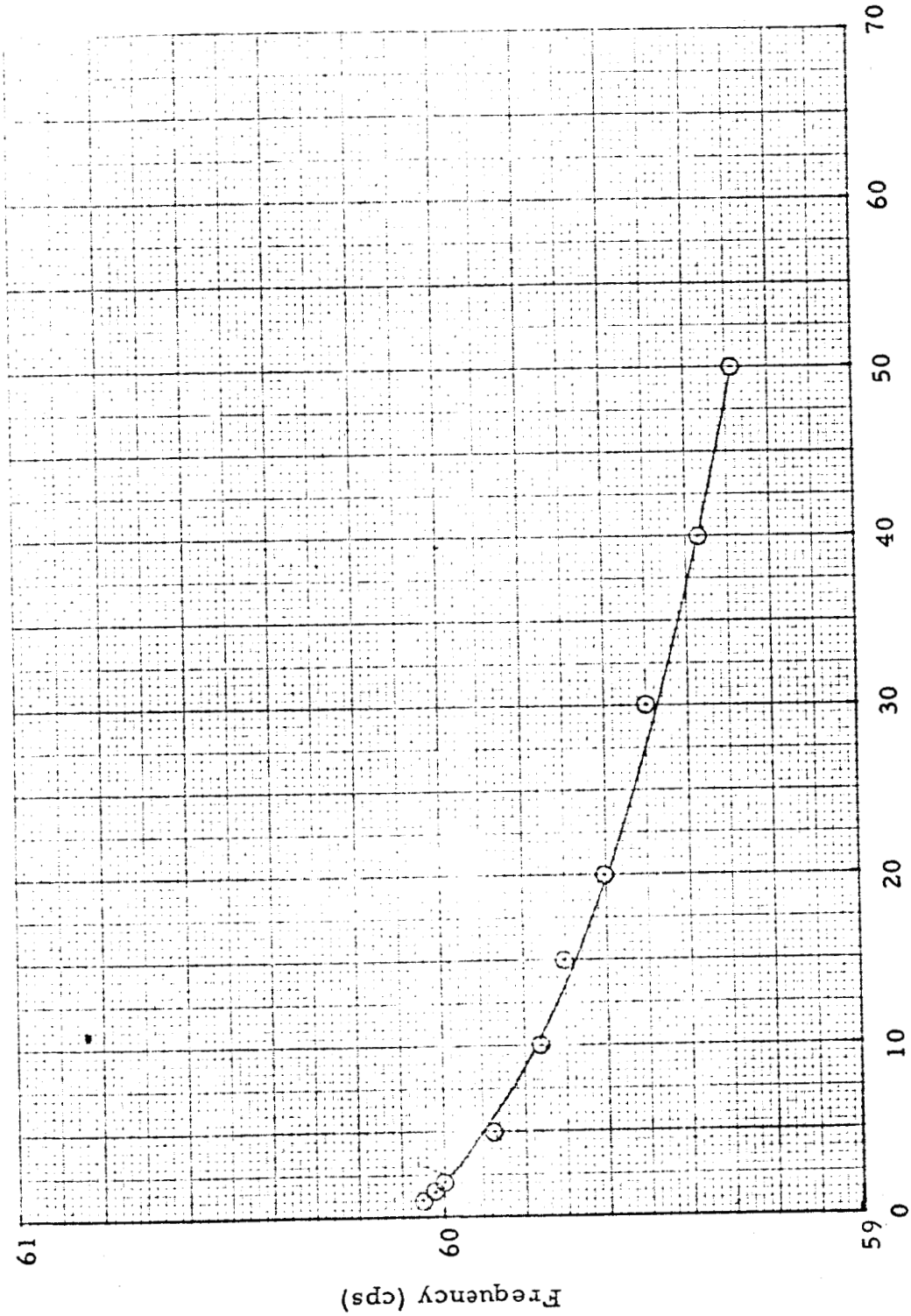

Figure 3 - Saturn SA-1 1/5 Scale Model Vibration Test Force vs Frequency (Empty Booster Fuel Shaker at Missile Station 345)

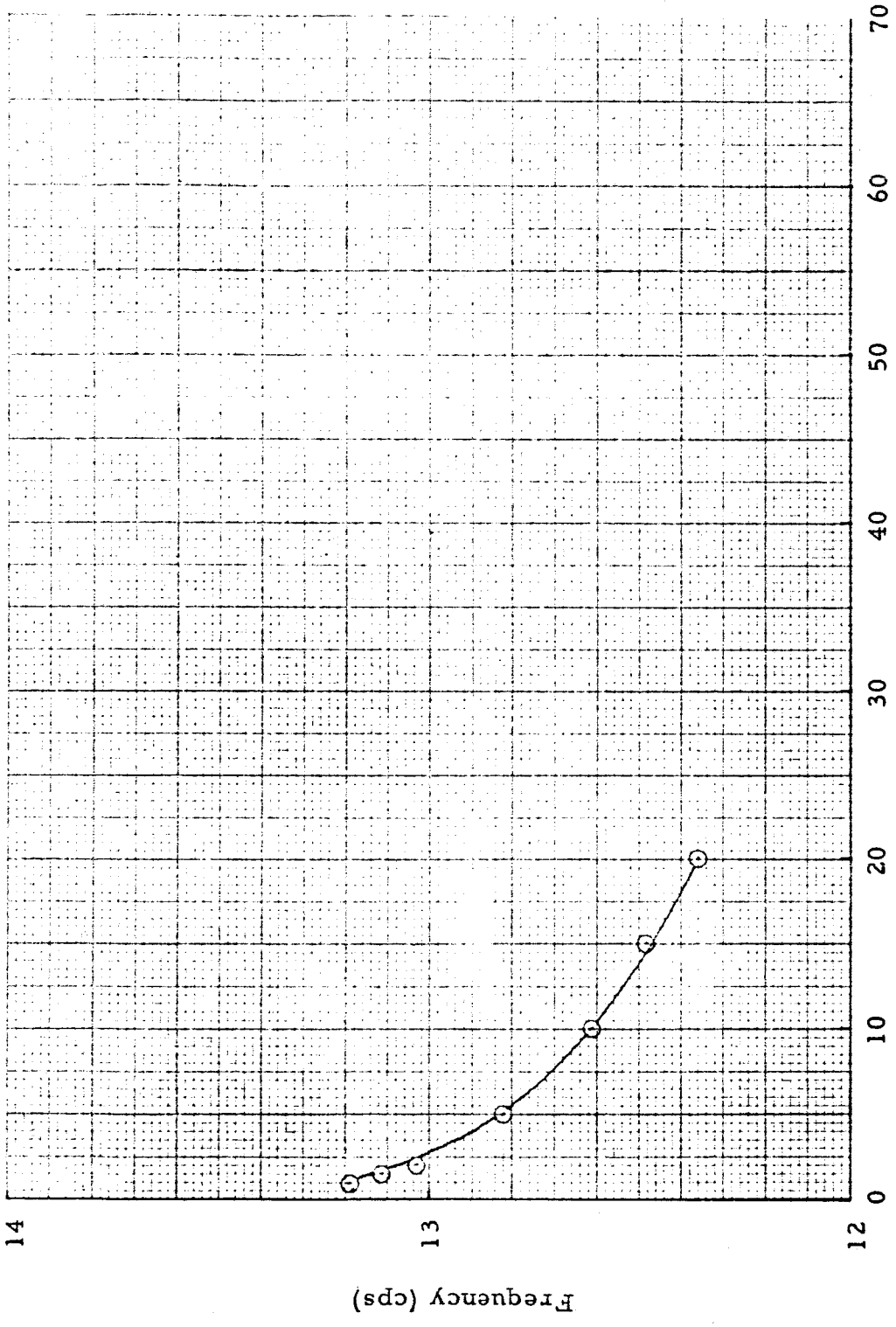

Figure 4 - Saturn SA-1 1/5 Scale Model Vibration Test Force vs Frequency (Empty Booster Fuel Shaker at Missile Station 345)

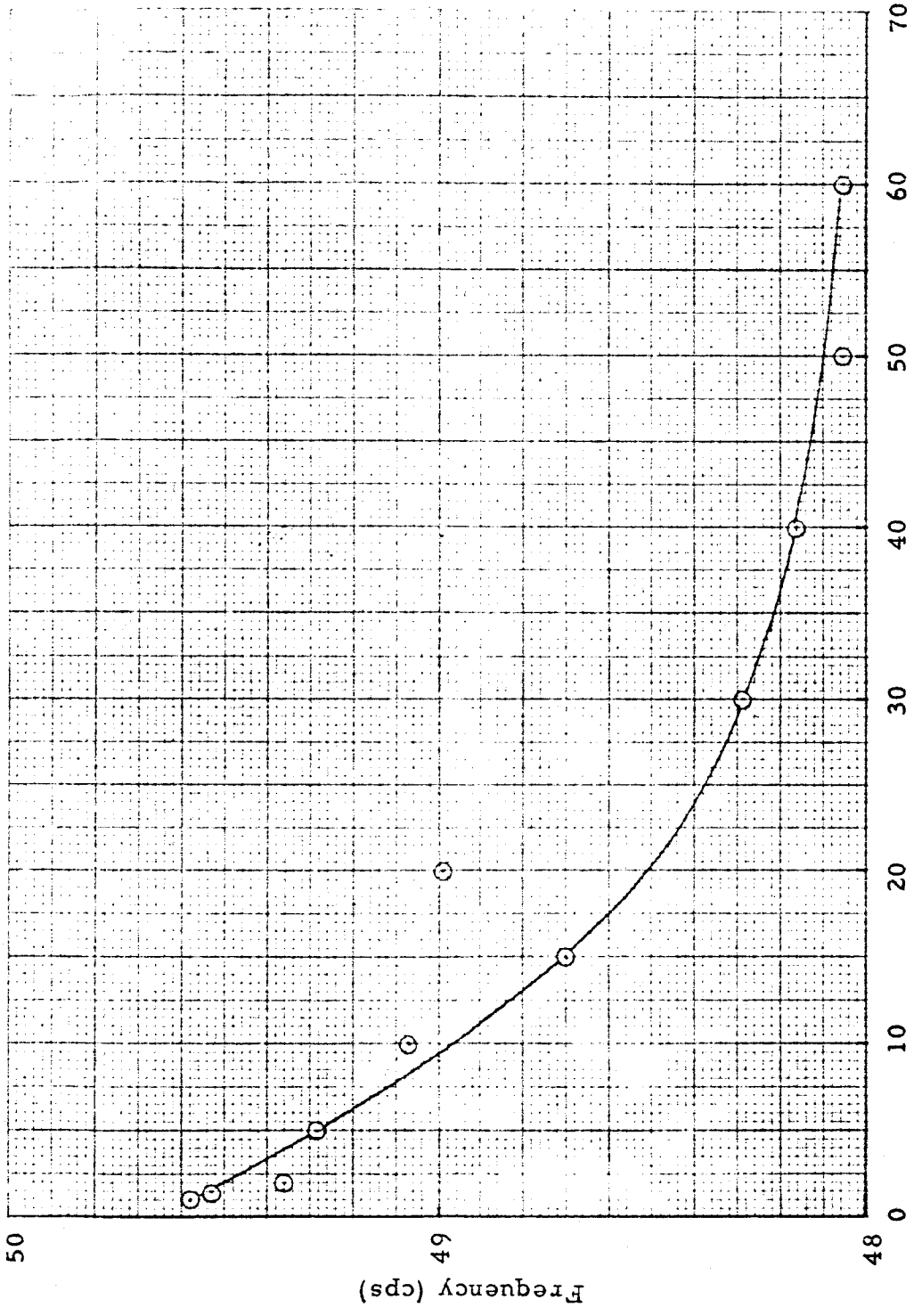

Figure 5 - Saturn SA-1 1/5 Scale Model Vibration Test Force vs Frequency (Empty Booster Fuel Shaker at Missile Station 345)

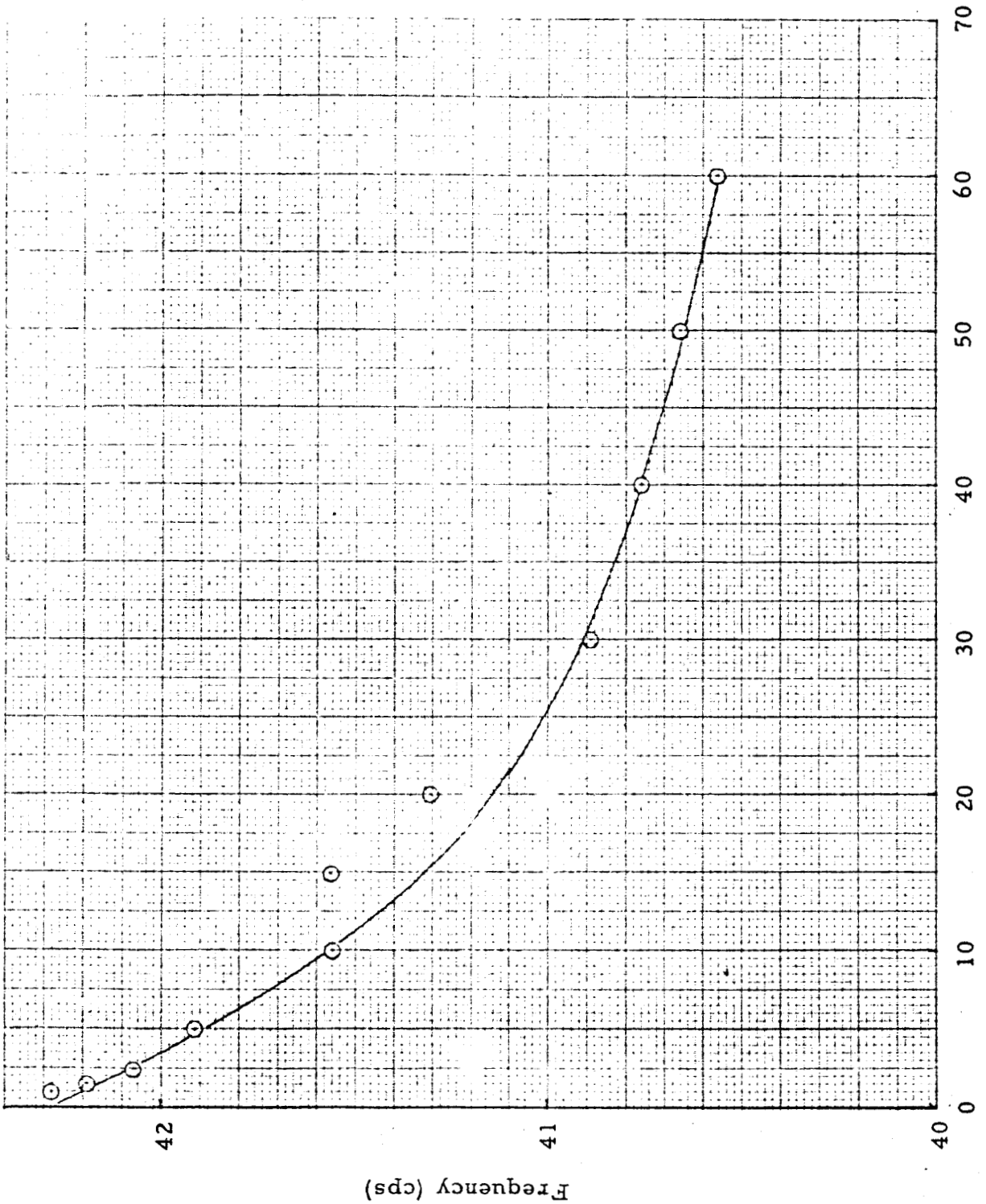

Figure 6 - Saturn SA-1 1/5 Scale Model Vibration Test Force vs Frequency

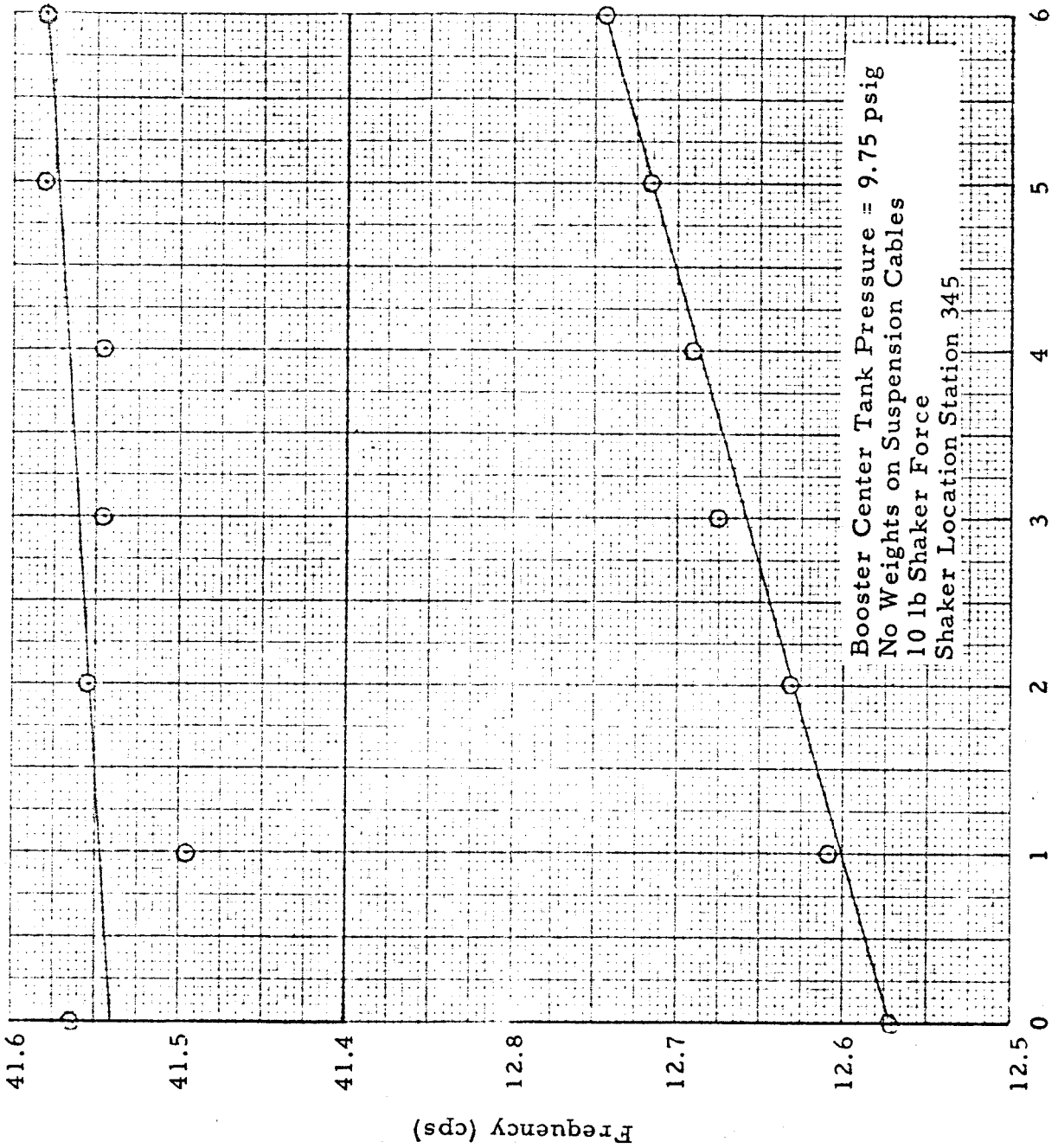

Figure 7 - Saturn SA-1 1/5 Scale Model Vibration Test Frequency vs Outer Booster Tank Pressure

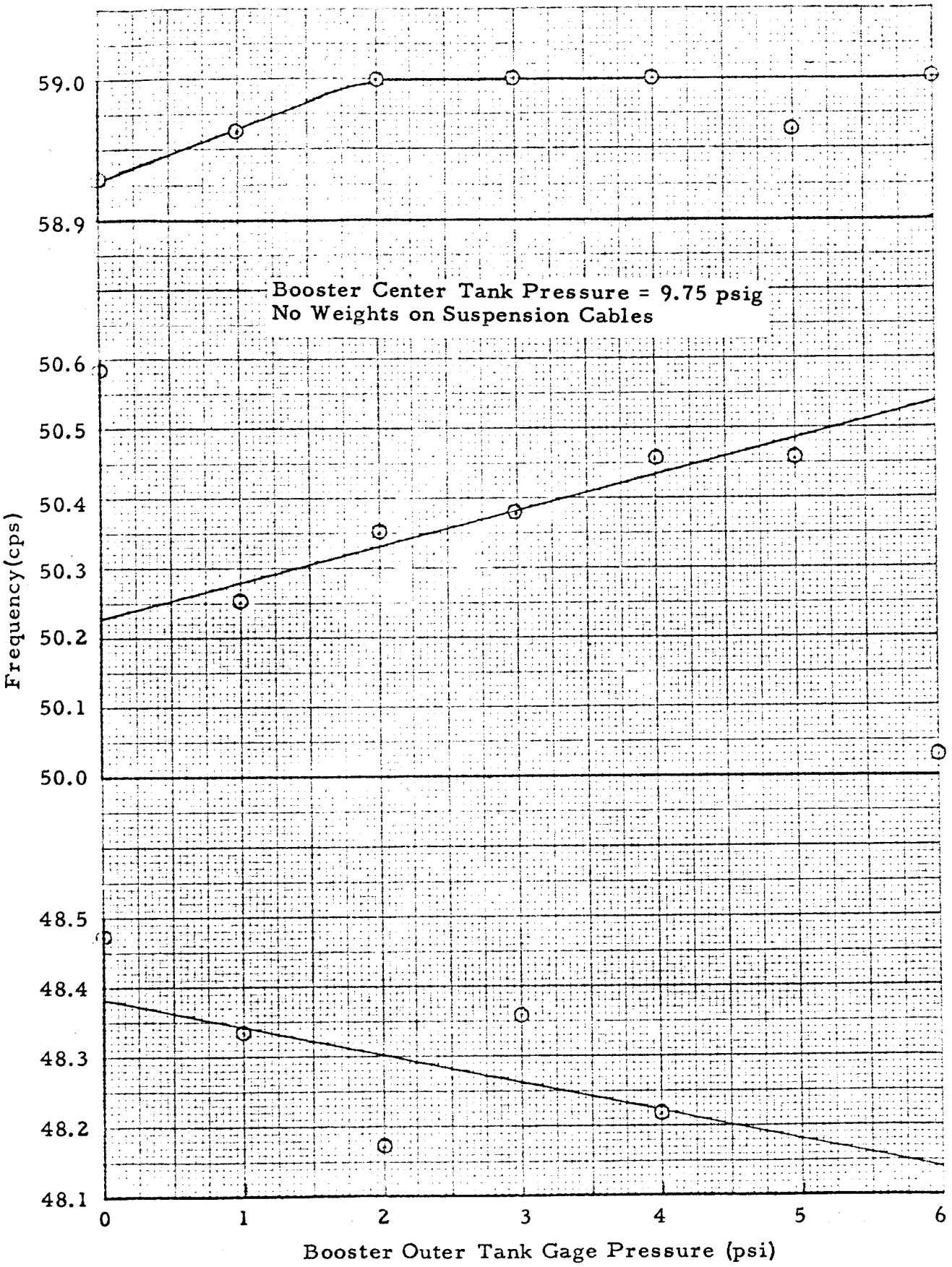

Figure 8 - Saturn SA-1 1/5 Scale Model Vibration Test Frequency vs Outer Booster Tank Pressure

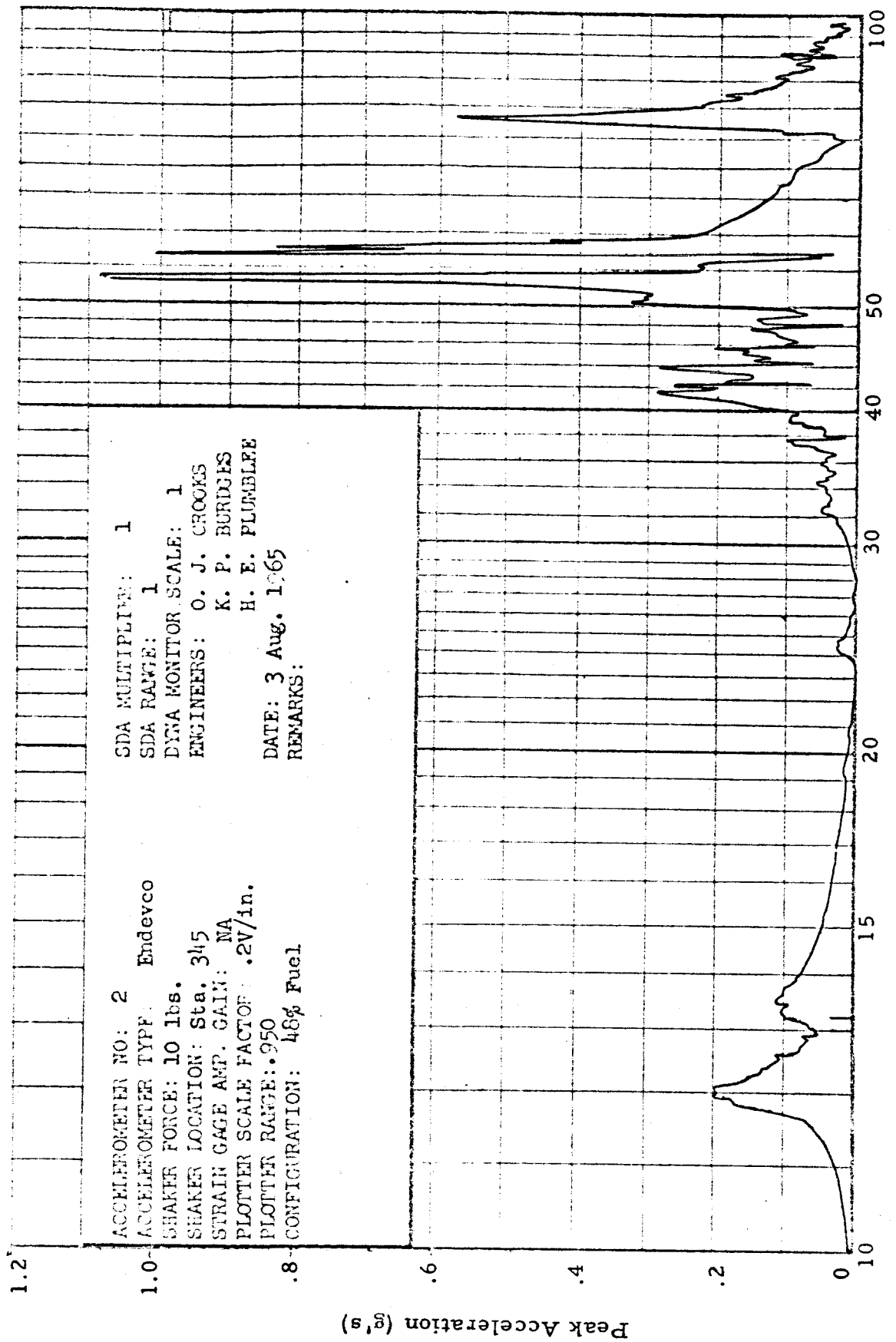

Figure 9 - Saturn SA-1 1/5-Scale Model Vibration Test Frequency Sweep

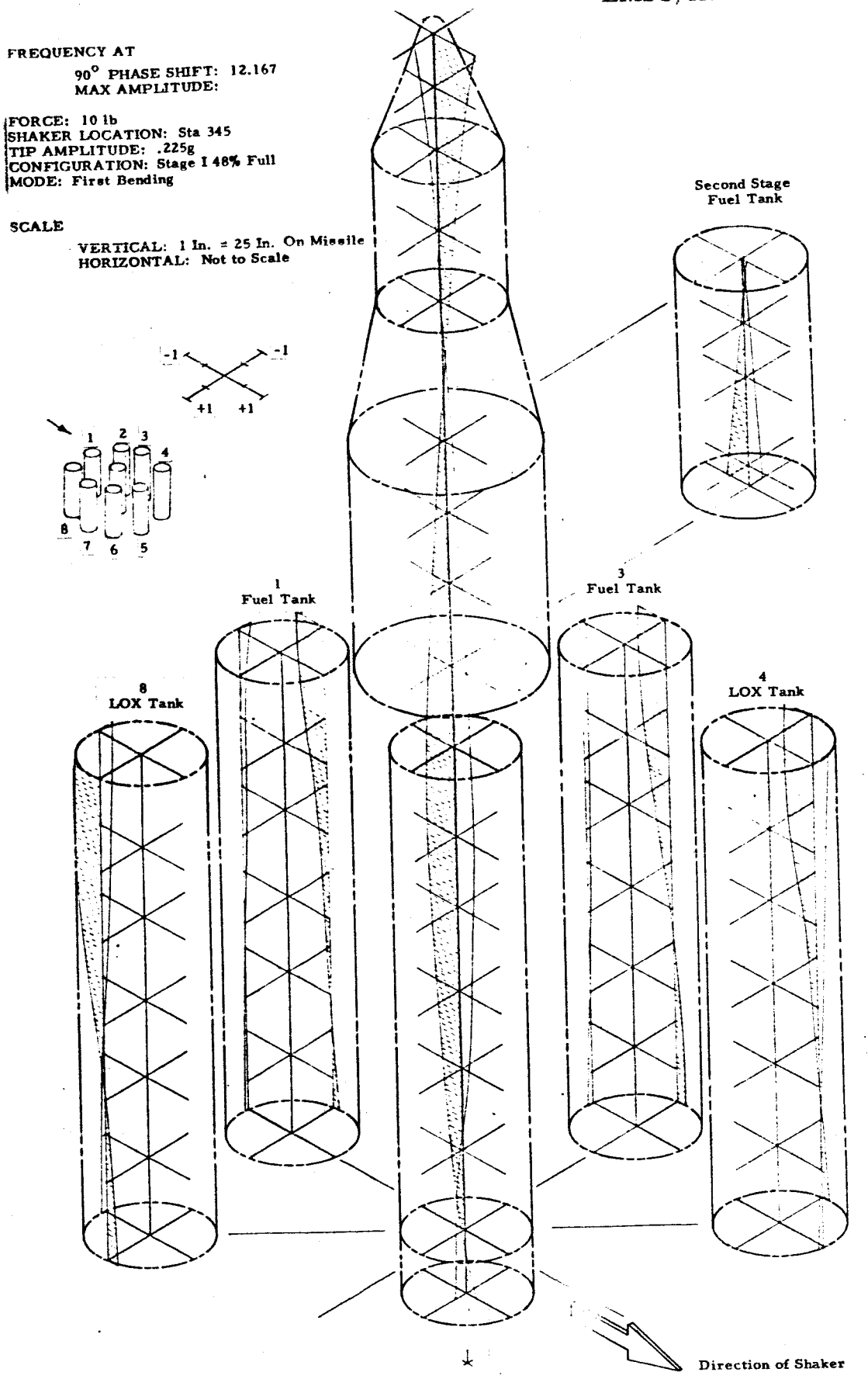
FREQUENCY AT
90° PHASE SHIFT: 12.167
MAX AMPLITUDE:
FORCE: 10 lb
SHAKER LOCATION: Sta 345
TIP AMPLITUDE: .225g
CONFIGURATION: Stage I 48% Full
MODE: First Bending
SCALE
VERTICAL: 1 In. = 25 In. On Missile
HORIZONTAL: Not to Scale
-1
-1
+1
+1
1
2
3
4
8
7
6
5
Second Stage Fuel Tank
1 Fuel Tank
3 Fuel Tank
8 LOX Tank
4 LOX Tank
Direction of Shaker

Figure 10

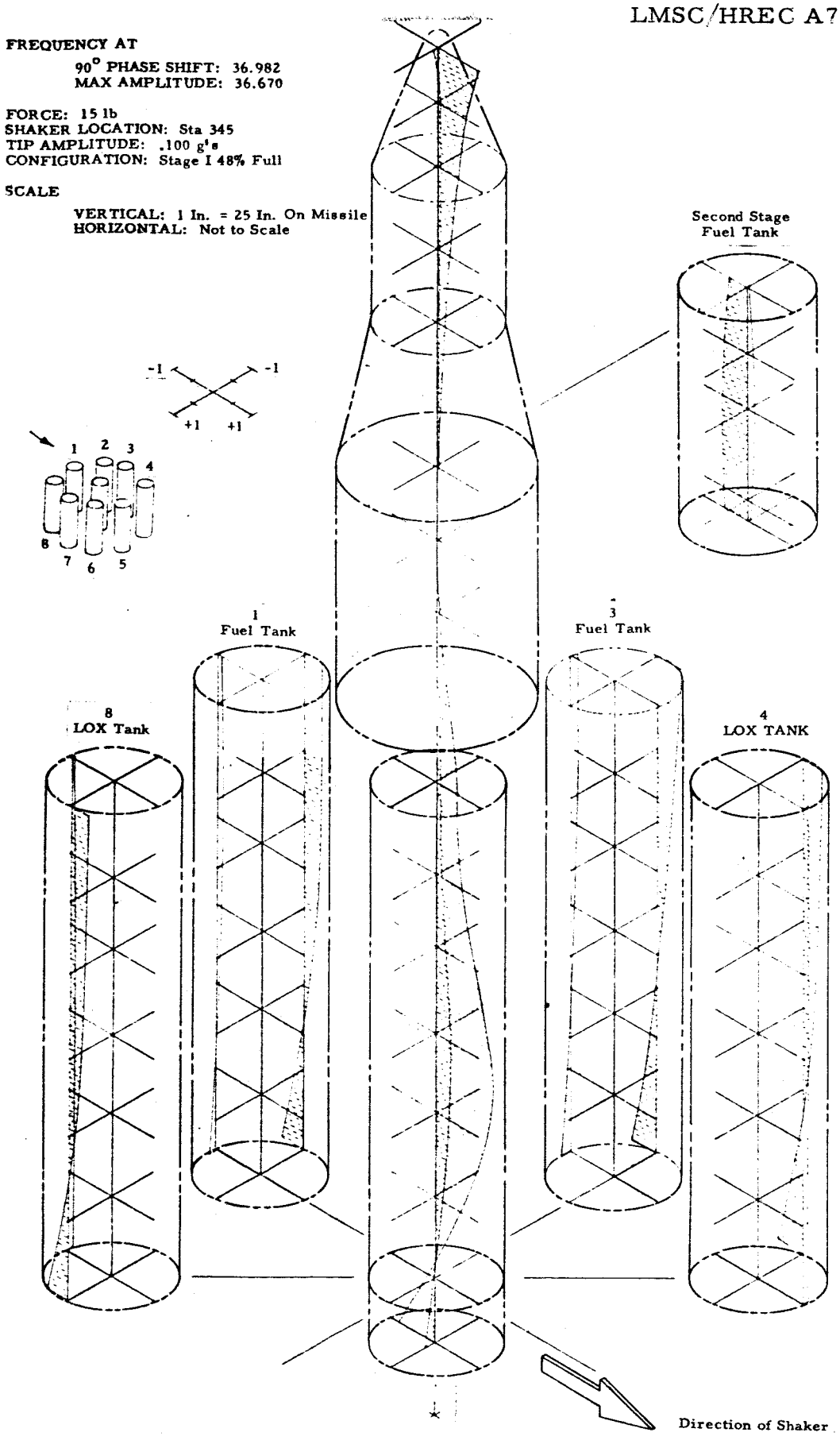
FREQUENCY AT
90° PHASE SHIFT: 36.982
MAX AMPLITUDE: 36.670
FORCE: 15 lb
SHAKER LOCATION: Sta 345
TIP AMPLITUDE: .100 g's
CONFIGURATION: Stage I 48% Full
SCALE
VERTICAL: 1 In. = 25 In. On Missile
HORIZONTAL: Not to Scale
-1
-1
+1
+1
1
2
3
4
8
7
6
5
Second Stage
Fuel Tank
1
Fuel Tank
3
Fuel Tank
8
LOX Tank
4
LOX TANK
Direction of Shaker

Figure 11

FREQUENCY AT

90° PHASE SHIFT: 45.517
MAX AMPLITUDE: 45.434

FORCE: 10 lb
SHAKER LOCATION: Sta 345
TIP AMPLITUDE: .270 g's
CONFIGURATION: Stage I 48% Full

SCALE

VERTICAL: 1 In. = 25 In. on Missile
HORIZONTAL: Not to Scale

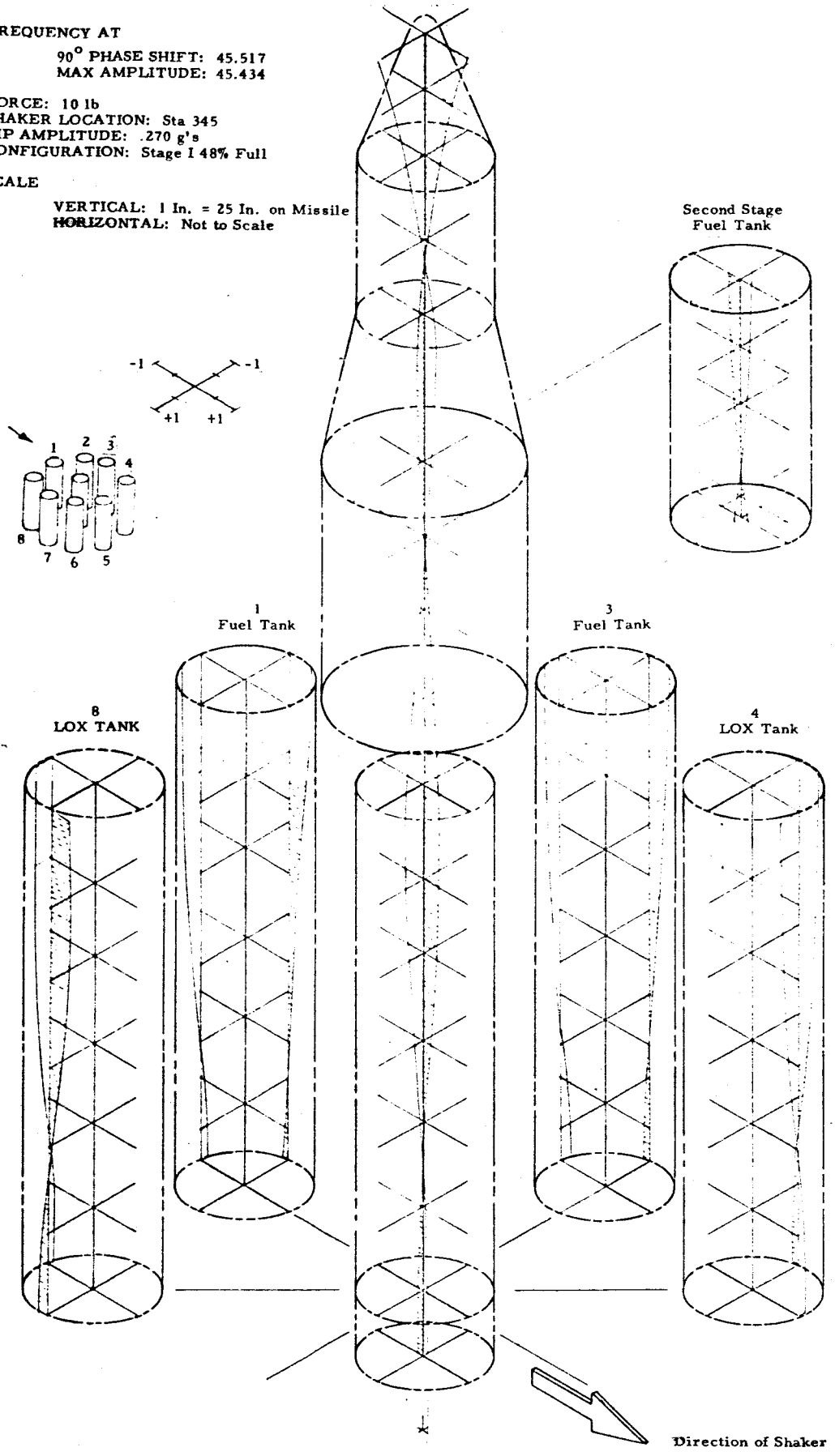

Figure 12

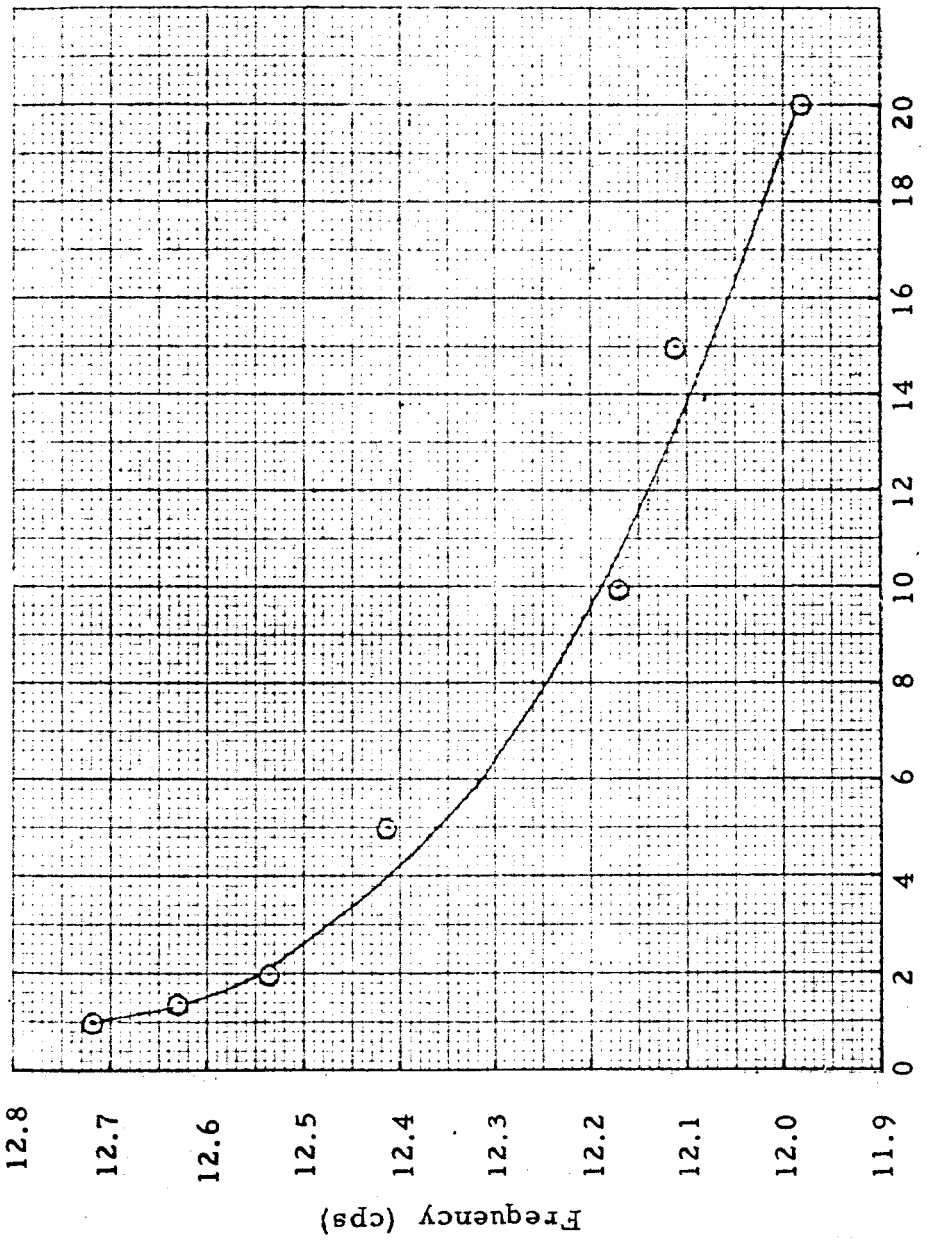

Figure 13 - Saturn SA-1 1/5-Scale Model Vibration Test Force vs. Frequency (48% Booster Fuel Shaker at Missile Station 345)

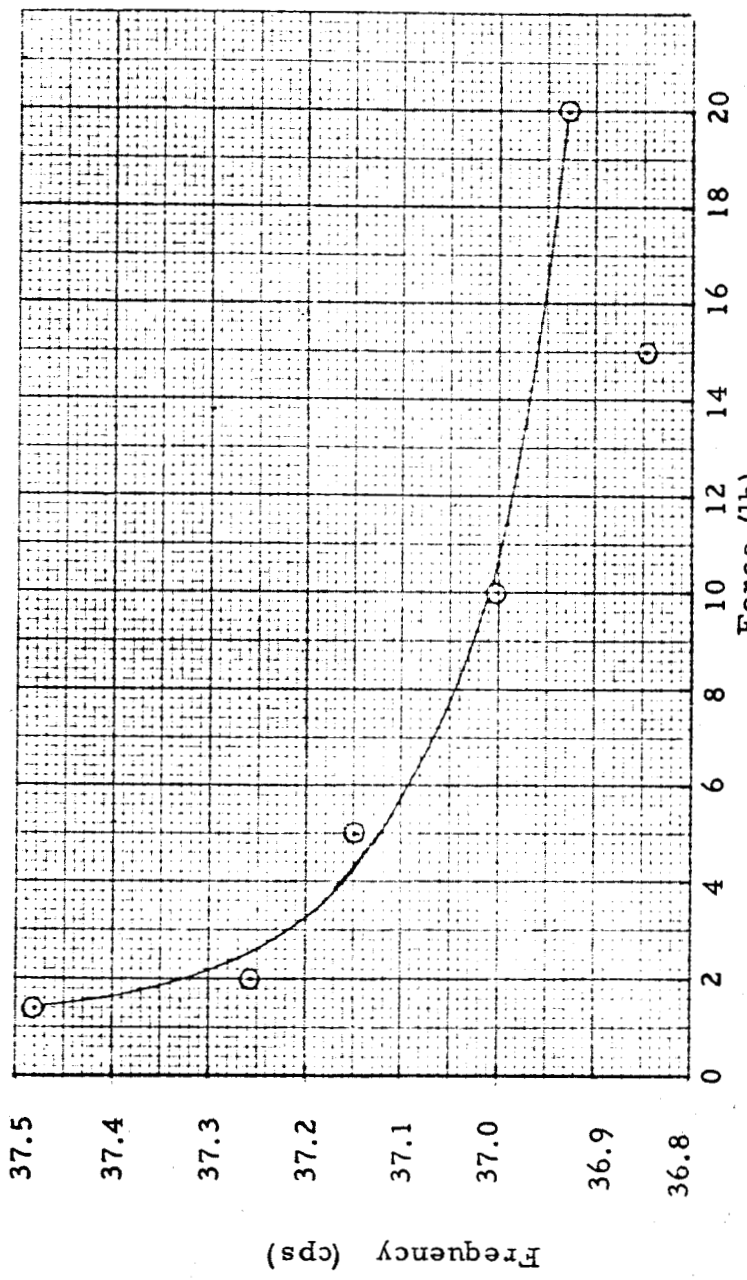

Figure 14 - Saturn SA-1 1/5-Scale Model Vibration Test Force vs. Frequency

(48% Booster Fuel Shaker at Missile Station 345)

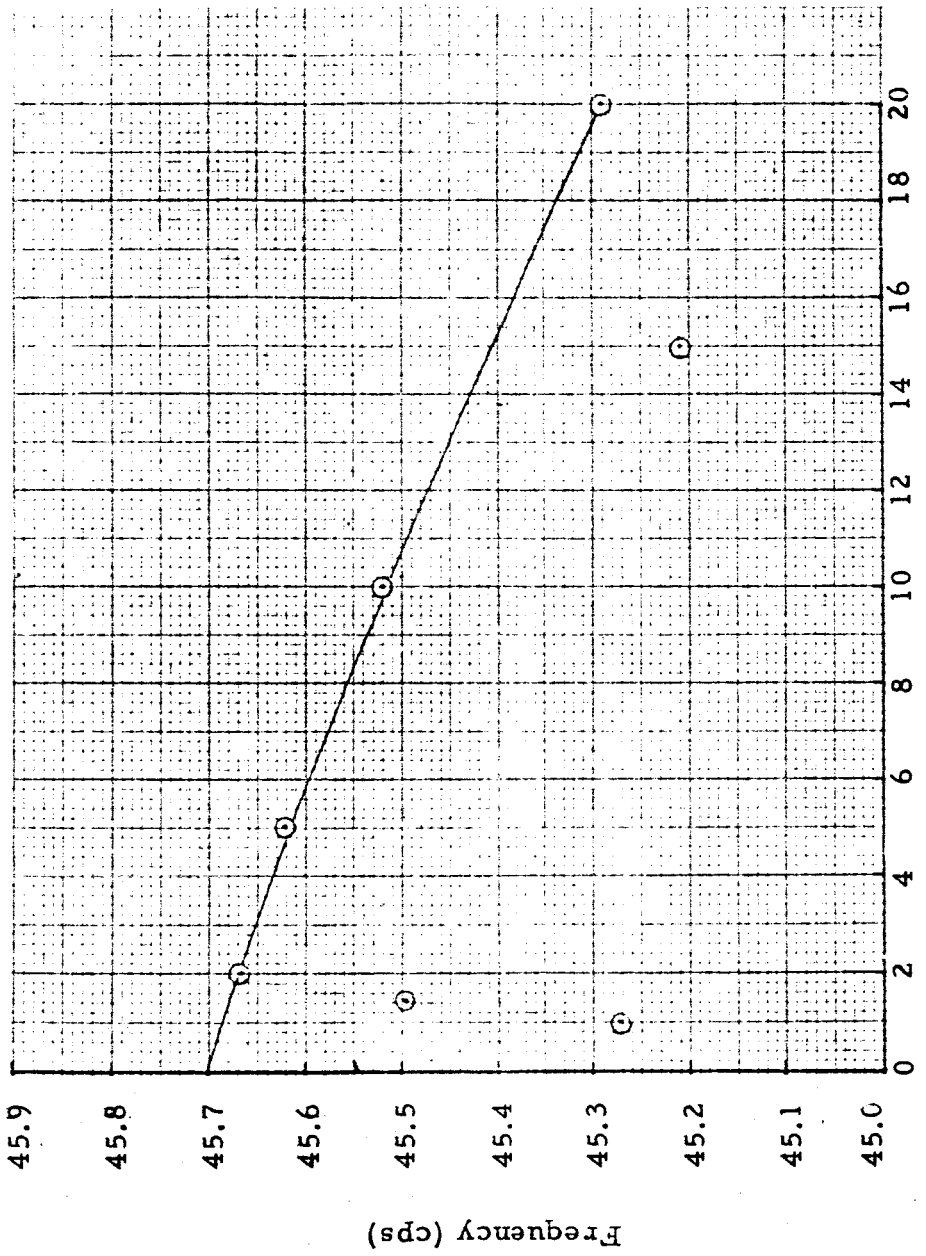

Figure 15 - Saturn SA-1 1/5-Scale Model Vibration Test Force vs. Frequency
(48% Booster Fuel Shaker at Missile Station 345)